Asymmetric Cochlear Processing Mimics Hemispheric Specialization

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The left hemisphere generally takes precedence over the right in processing of speech sounds and performance of sophisticated language functions, whereas the right hemisphere is primary in the processing of tonal stimuli and music. Converging evidence from diverse methodologies has revealed that left and right auditory regions may be individually specialized for processing of sounds based on acoustic properties. Rapidly changing signals are processed preferentially in auditory areas of the left hemisphere because of enhanced temporal resolution, and tonal stimuli are best processed in auditory areas of the right, reflecting specialized abilities for spectral resolution (*1*). Behaviorally, reaction time is faster and stimulus identification is more accurate when a subject's right ear is presented with speech-type stimuli or when the left ear is presented with tonal information (*2*). The strength of crossed pathways from the ear to the auditory cortex is credited with the ear-advantage phenomenon. Asymmetry of function at the level of the ear has not generally been considered in this process.

Otoacoustic emissions (OAEs) reflect activity from active mechanisms of the outer hair cells that serve to amplify acoustic energy in the cochlea (*3*). OAEs require no innervation, but they are modulated by the medial olivocochlear efferent system in the brainstem (*4*). A transducer fit into the ear canal provides sound to activate an OAE. Energy generated in the cochlea is transmitted back into the middle ear and ear canal and is measured by a microphone in the transducer-probe assembly. Transient-evoked otoacoustic emissions (TEOAEs) are stimulated by clicks presented in rapid succession. Distortion-product otoacoustic emissions DPOAEs) are evoked by pairs of continuous tones. The amplitudes or signal-to-noise ratios (SNRs) of TEOAEs and DPOAEs reflect the magnitude of active cochlear amplification mechanisms, although by slightly different processes (*5*).

DPOAEs to a set of tone pairs and TEOAEs generated by clicks (80/s) were obtained from a pool of 3011 infants. Data were further selected to include only those infants from whom clear TEOAE and DPOAE responses (with an average SNR of 3 dB or greater) were obtained in both ears. This reduced the pool to 1593 infants for whom data was analyzed. Details of our methods have been published (*6*, *7*) and are available online (*8*). The test order for ear and OAE type was randomized. SNRs from frequency regions from 1500 through 4000 Hz were averaged for both types of OAE.

Figure 1 reveals that the average TEOAE SNR generated by clicks was larger when elicited in right ears, and the average DPOAE generated by tones was larger from left ears. This pattern of TEOAE result was seen in 855 (53.6%) of infants, and the DPOAE pattern was seen in 825 (51.75%). When the two measures are combined, 324 infants demonstrate the average trend and 241 demonstrate the opposite (larger TEOAEs in the left ear and DPOAEs in the right). The remaining infants showed mixed trends. Repeated measures analysis of variance (*8*) revealed significant ear-by-OAE-type interaction ($P < 0.0001$). No significant interaction was found between ear and sex. Post hoc tests found significant ear effects for DPOAEs ($P = 0.0010$) and for TEOAEs ($P = 0.0013$). The results indicate a tendency for the cochlea to provide greater amplification to stimuli that will also be preferentially processed in the auditory areas of the contralateral hemisphere. Others have found larger average TEOAEs in the right ear of neonates (*9*), but no clear ear difference has been reported for DPOAEs.

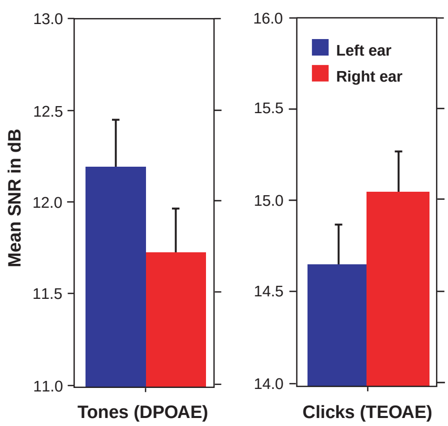

Fig. 1. Mean OAE SNR in response to tone pairs (f1 and f2) presented with f1 = 65 and f2 = 50 dB sound pressure level (SPL) tones, and in response to 80-dB peak SPL clicks. Error bars represent the 95th percentile range.

Both speech and tonal stimuli have been shown to elicit larger evoked potential activity over the left hemisphere in 4-month-old infants (*10*). This study indicates that stimulus-guided asymmetry is present at the level of the cochlea before it is evident in the auditory cortex. The developmental time course of ascending and descending neural pathways connecting the ear to the auditory regions of the cortex is complex. Moore (*11*) has found that afferent connections in the auditory system between the brainstem and cortex are immature at birth. The time of development of descending neurons from the cortex to inferior colliculus is not established. Olivocochlear efferent neurons in the brainstem, however, are mature before birth (*12*) and have been shown to modulate the OAE in newborns (*13*). The stimulus-guided asymmetrical nature of OAEs in infants suggests that, at the early stages of auditory system development, initial processing of sound in the auditory system at the level of the cochlea and brainstem may serve to facilitate later development of hemispheric specialization for sound processing.

References and Notes

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